P0685

Evaluation of Discrete Angles Rotation Degradations for Myocardial Perfusion Imaging

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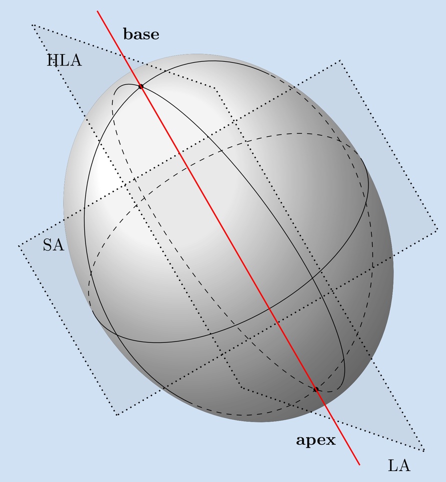
Introduction & Purpose

For myocardial perfusion imaging, the tomographic transaxial cardiac volume must be reoriented in the standard views for inter-patient comparison and diagnosis accuracy, as advised by the EANM guidelines.
The volume is then resampled and displayed in the standard HLA, VLA and SA axis.

Rotation of digital images defined on discrete grid introduce image degradation and artifact arising from the lack of perfect match between continuously rotated grid and the original one. As a result, every rotation has to be considered cautiously and be held in the manner to minimize the quantification error.

The goal of this poster is :
1) to compare existing rotation algorithms for nuclear medicine images (with their specific spectral content),
2) to use a novel method (Svalbe) both based on discrete angle rotation and image sampling to ensure an one-to-one pixel mapping,
3) to measure rotation operator defaults using the same discrete angles for all tested methods.

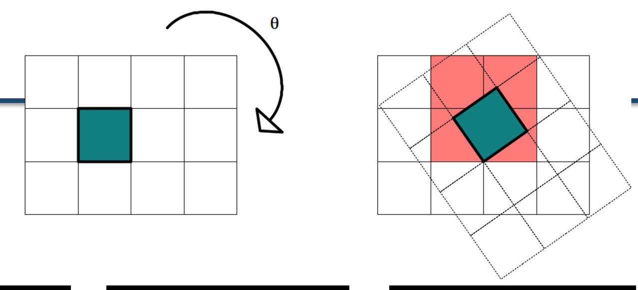


Subjects & Methods

Continuous rotation of a 2D image

Sinogram data → (Reconstruction) → Discrete image → (Interpolation) → Continuous image → (Continuous Rotation) → Continuous rotated image → (Sampling) → Discrete rotated image

- Nearest neighbor
- Linear
- Cubic B-spline

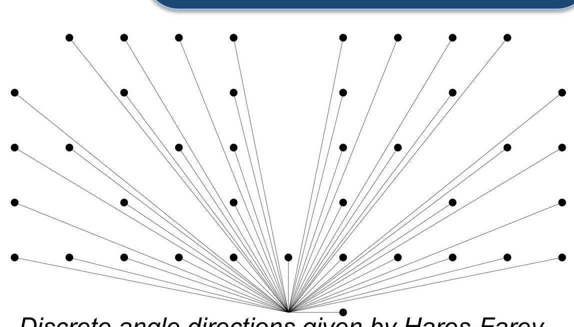


Left to right: Original PET image, rotation of angle θ using nearest-neighbor interpolation, rotation of angle θ using cubic spline interpolation $\theta = \arctan(1/2)$

Discrete rotation of a 2D image

Discrete sinogram → (Discrete Rotation) → Rotated sinogram → (Reconstruction) → Discrete rotated image

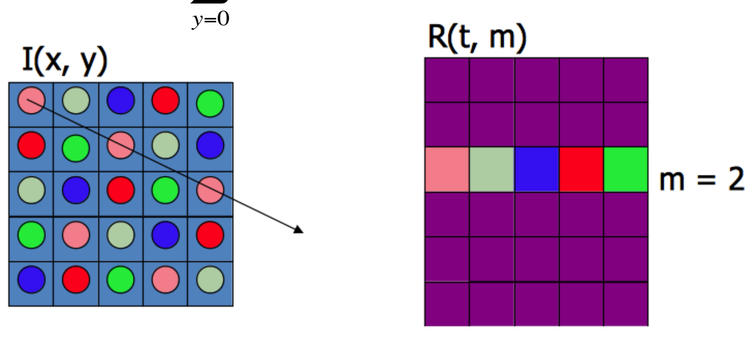
- Based on **Finite Radon Transform**
- Upscale rotation directly implemented in Radon space
- Reversible and lossless
- Rotations only for Haros-Farey angles

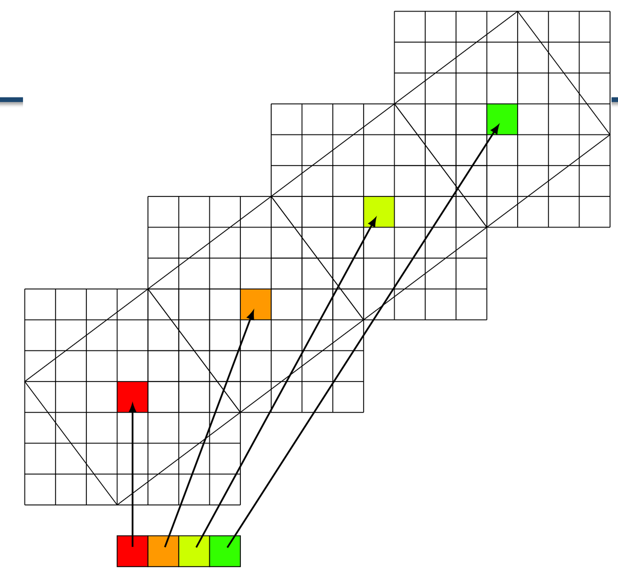


Discrete angle directions given by Haros-Farey series of order 5

FRT is an exact, discrete and periodic form of the Radon transform. It maps a p size square image I(x,y) to a p×(p+1) projection image R(t,m), where each pixel of R(t,m) contains the projection value of the original image onto a discrete-angle ray.

$$R(t,m) = \sum_{y=0}^{p-1} I(<my+t>_p, y)$$





Each row m represents a discrete direction of projection. By re-arranging cleverly the rows, we can perform rotations in the projection space.

Experiments

2 kind of experiments are used :
1) kN rotations of 2π/N angle. 2π/N is chosen to be a discrete angle. This scheme is only used for continuous rotations (c.f. Table 1),
2) Rotation of angle (p_1,q_1), followed by (p_2,q_2). The resulting image is then rotated one last time by the global reverse angle (p_1p_2-q_1q_2,q_1p_2+p_1q_2). This scheme is tested for continuous and discrete rotations (c.f. Table 2).

Error measurement using 2 metrics

Mean Square Error (MSE) – the l^2 norm of error image : $MSE = \frac{1}{PQ}\sum_{x=0}^{P-1}\sum_{x=0}^{Q-1}\left(I(x,y) - I'(x,y)\right)^2$

Peak Signal to Noise Ratio (PSNR) : $PSNR = 20\log(\frac{255}{\sqrt{MSE}})$

Results

Table 1: kN rotations of 2π/N

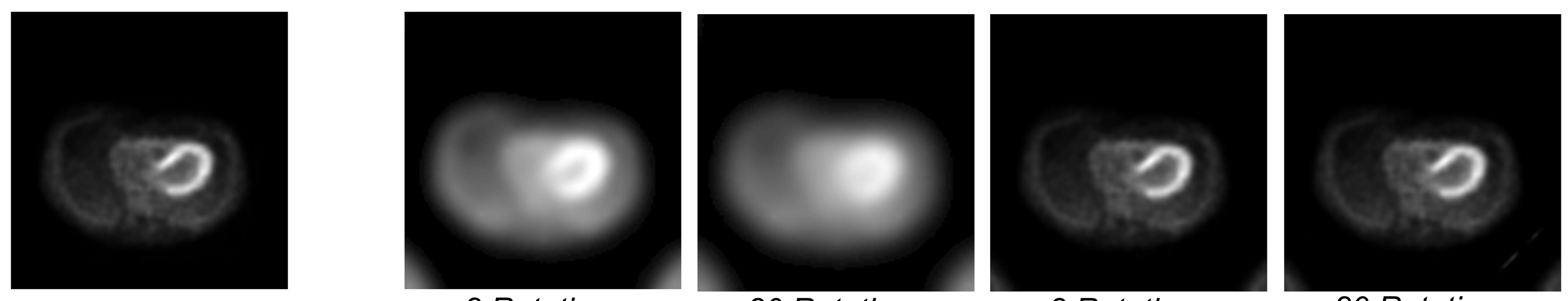
Method	PET				CT			
	8 Rotations of 45°		80 Rotations of 45°		8 Rotations of 45°		80 Rotations of 45°	
	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR
Nearest	24.90	34.17	24.90	34.17	145.41	26.50	145.41	26.50
Bilinear	25.29	34.10	98.55	28.19	155.29	26.22	326.36	22.99
CubicB- spline	20.64	34,98	20.92	34.93	115.17	27.52	139.64	26.68
High order (Spline 7)	21.93	34,72	71.57	29.58	116.87	27.45	267.27	23.86

For continuous rotations, cubic spline seems to give the best results. Even higher order spline give worse results. We discourage the use of bilinear interpolation since it blurs dramatically the image. We also discourage the use of even degree splines, as for example SP2 which gives rise to strong aliasing artifacts.

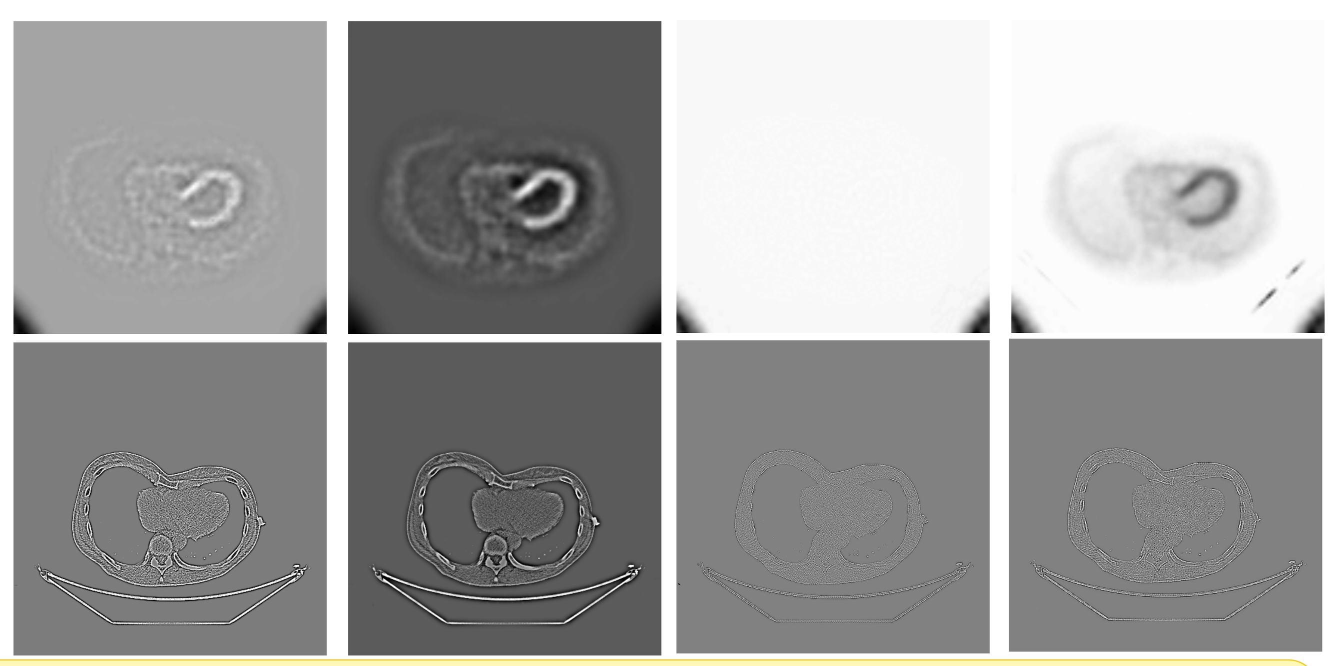
Table 2: Rotation of angle (1,1) followed by (2,1) and reverse rotation by (1,-3)

Method	PET		CT	
	MSE	PSNR	MSE	PSNR
Nearest	10.18	38.05	162.29	26.03
Bilinear	1.14	47.56	98.85	28.18
Cubic B-spline	0.01	66.55	82.12	28.99
Discrete FRT rotation	0.08	59.10	146.65	26.47

The discrete FRT-based rotation does not give the best MSE values, but it does not introduce any blur. Moreover, the original pixel intensities are preserved thus the rotation is totally reversible and lossless, which is very appreciable for quantitative analysis based on pixel intensity.
Some drawbacks, like the magnification of image size increases memory usage and the periodic sampling of FRT needs a specific mapping to achieve discrete rotation from real acquisition.



PET ^{82}Rb CT — *8 Rotations (Bilinear)* — *80 Rotations (Bilinear)* — *8 Rotations (Cubic Spline)* — *80 Rotations (Cubic Spline)*



Corresponding error images

Conclusion

The key points of our method are:
- The method is fully discrete so no assumption is made about an underlying continuous model, making it fast, exact and reversible
- It is performed into a discrete projection space, close to the data acquisition space. Thus no tomographic reconstruction has to be made prior to reorientation, minimizing the smoothing effects of interpolation.

Future work: Effects of both reconstruction and reorientation have to be assessed simultaneously. For this purpose, we need estimators of left ventricle orientation directly into the projection space.

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